Activity 2 - Concept study on next generation icebreakers

Sub activity 2:1
Atle/Urho model test,
Further testing of other new concepts
New “Loose Bow”-concept.

Sub activity 2:2
Desktop study on fuelling possibilities

Sub activity 2:3
Study on relative efficiency between models

Sub activity 2:4, 2:5 and 2:6
Desktop study on different ownership, chartering and operating arrangements. Study on different financing options for new icebreaker.

Generally Act 1 & 2 provide tools to decision support for composition of next generation icebreaker fleet including financing and service concepts
“Different horses for different courses”
Replacement of ageing infrastructure
icebreaking capacity

- Worlds infrastructure icebreaker fleet is ageing, same applies to Baltic icebreakers
- Icebreakers differ, different locations and operations require different capabilities
- Reliable and cost efficient icebreaking capacity to infrastructure winternavigation, chartered from mature commercial icebreaking market, is still far in the future.
- Real increase in utilisation rate for icebreakers which form the core of area specific icebreaking capacity, how intimidating it might sound, is economically very challenging. On the other hand, for additional capacity this concept could be efficient in the future.
Removable icebreaker bow concept
ILS Oy Consulting Naval Architects & Marine Engineers

Ship Design Expertise

IN THEORY AND PRACTICE

- Founded 1988
- Personnel ~15
- Independent, Finnish-owned company in Turku
- Recent clients in Finland, Sweden, Norway, Denmark, Estonia, Russia, Kazakhstan, Singapore, Canada

- Conceptual Design
- Basic Design
- Workshop Drawings
- Contract Documents
- Classification Documents
- Inspection of Documents
- Site Supervision
- Model Tests (ice and open water)
- Full Scale Tests (ice and open water)
- General Consulting Related to Ice
- Research and Development
Removable bow – old invention

1892 German patent of icebreaking bow to be placed in front of a ship
  • Used generally e.g. in Dutch rivers

Spoon-shaped removable Wärtsilä bow from 1986
  • Used with tug Protector e.g. in lake Saimaa as an icebreaker
ILS Removable icebreaker bow concept

General
The idea of the removable bow icebreaker is based on the use of a pusher vessel of smaller size and lower power than conventional icebreaker:
• connect it to a removable bow with propulsion.
• The pusher can be e.g. an existing vessel or a newbuilding optimized for its primary tasks.
• In this way the investment costs are limited to the construction of a removable bow with propulsion.
Design requirements

- Speed in 0.8 m level ice ahead min about 6 knots (high enough escort speed)
- Total propulsion power about 11 MW
- Waterline breath of removable bow about 24 m
- Fixed coupling of pusher and removable bow
- The ice strengthening of the removable bow and its propulsion to correspond present baltic icebreakers
- The pusher ice class to be min 1A Super

I.e. removable bow icebreaker is designed for Baltic ice conditions excluding hard Golf of Bothnia operations.
Studied propulsion alternatives

Version alt. 1A/1B
- 1x6 MW pulling azimuth at bow

Version alt. 2
- 2x3 MW pulling azimuth at bow

Version alt. 3
- 2x3 MW conventional shafts at bow

Version alt. 4
- 2x3 MW conventional shafts at stern reamer area
Removable Bow, alt 4 (conventional shafts at reamer areas, pat pend)
- Propulsion power: 2x3 MW
- L: 50,6 m
- Bwl: 24,0 m
- T: 6,0 m

Pusher (multipurpose oil and chemical recovery vessel Louhi)
- Propulsion power: 2x2,7 MW
- L: 71,4 m
- Bwl: 14,5 m
- T: 5,0 m
- BP: 64 t

Combination (The removable bow with pusher results in an icebreaker hull form with reamer bow and highly inclined sides)
- Propulsion power: 11,4 MW
- L: 93,0 m
- Bwl: 24,0 m
- T: 6,0 m
- BP: 130 t
Target of the model tests

The Target of the model tests was to study the characteristics of:
- Removable bow icebreaker concept generally compared to conventional icebreaker designs and
- To test the novel propulsion system
The new operational characteristics in ice were specially studied.

In heavy ice channels and ridges the bow propellers have
- direct interaction with ice
- and also the suction and flush of the propeller flow

are used to

- Break heavy channel/ridge at vessel sides
- Flush the vessel sides and push the ice floes aft
The new operational characteristics in ice were specially studied.

This, together with the wide smoothly shaped reamer bow makes it possible to go through heavy ridges continuously without ramming.

In manoeuvring the use of the high steering moment, given by the bow reamer propellers, adds vessels manoeuvring performance.
The main target of the open water model tests was to measure values needed for the ice model test analysis.

Tests included:

- Propeller open water tests
- Bollard pull and towing tests both ahead and astern
- Resistance tests
- Self propulsion tests

![Graph showing PD vs Vs (kN)]
Open water model tests

It can be seen that:

- The propulsion power is at the same level as in Atle/Urho class.
- The max speed of the removable bow icebreaker is over 16 knots.
- The power needed in open water is lower than that of the multipurpose icebreaker.
Ice Modeltests

- Level ice ahead (0.6 m/0.87 m)/astern (0.6 m)
- Consolidated channel ahead/astern (1.2 m)
- Unconsolidated channel ahead (1.8 m)
- Breaking out of channel
- Consolidated ridge (Urho´s ridge 9-5 m) ahead
- Consolidated ridge (6 m) ahead and astern
- Turning tests ahead and astern
Level ice ahead $H_{\text{Ice}} = 0.87$ m

- Speed 5.3 kn; Atle/Urho class 7.7 kn
- Speed scaled with Atle/urho power and breath results to 7.1 kn
- Ice interaction of bow propellers was quite high, ice floes lean against the shaft supports, further development would be useful
Level ice astern $H_{Ice} 0.6$ m

- Speed 6.6 kn, at same level like Botnica and higher than Urho
- Ice interaction with propellers quite low
Consolidated channel ahead

$H_{\text{Ice}}$ 1,2 m and 1,8 m

- Ice resistance in channel was quite low
- The wider bow with reamer propellers decreased the friction resistance
Consolidated channel astern $H_{\text{Ice}}$ 0.6 m

- The bow propellers flow keep reamers clean of ice when going astern
Consolidated ridge $H_{\text{Ice}}$ 6 m

- Ridge performance excellent
- Reamer propellers interaction with ice as well as suction and flush effect broke efficiently ridges and flushed the vessel sides
- The vessel was able to go through the ridges with one attempt both ahead and astern
Consolidated ridge (Urho´s ridge)

$H_{\text{Ice}}$ 9-5 m

- Use of aft thrusters dynamically helpful when the vessel was stopped
Turning test ahead $H_{\text{Ice}}$ 0.6 m

- Maneuvering capability was excellent
- At same level as that of multipurpose icebreakers with azimuth thrusters
- The vessel is able to turn almost on spot both ahead and astern
Summary

• The concept study and model tests showed that the removable bow icebreaker is feasible as a Baltic icebreaker

• The investment costs of the bow is about 25% of the price of a purpose built icebreaker

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Activity 2, Trimaran and Oblique icebreaker concepts

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Project Manager
Aker Arctic Technology Inc
Helsinki 2016-03-29
Aker Arctic Technology Inc

- Founded in 2005 as independent company as spin-off from Kvaerner Masa-Yards arctic research and development organisation
- Employs today about 50 persons, experienced naval architects and arctic engineering specialists
- Annual turnover about 14 million Euros
- Aker Arctic’s shareholders today:
  
<table>
<thead>
<tr>
<th>Shareholder</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Finnish Industry Investment Ltd</td>
<td>66.4 %</td>
</tr>
<tr>
<td>ABB Oy, Finland</td>
<td>16.8 %</td>
</tr>
<tr>
<td>Aker Solutions AS, Norway</td>
<td>16.8 %</td>
</tr>
</tbody>
</table>

- Working globally with major oil companies, industrial companies, shipyards, ship owners, classification societies and emerging industries
- Main services are ice going ship design and engineering, ice model testing and other arctic related consultation and engineering
Aker Arctic Technology Inc

- Main Office Helsinki
- Moscow Representative Office
- Akac Inc. (100% subsidiary), Victoria and St John’s
Trimaran icebreaker

![Graph showing ice resistance vs. width (m) for different models and calculated values.](image-url)
Trimaran icebreaker

- Aker Arctic has carried out extensive R&D around the trimaran icebreaker concept in the past years
  - Ice model tests
  - New calculation method for performance prediction of icebreaking trimaran
  - Crossdeck strength analysis
- As part of the WINMOS project, the trimaran icebreaker idea was refined into a realistic vessel concept
- Design basis:
  - Icebreaking vessel with ability to break wide channel with reasonable propulsion power
  - Secondary use as capable oil recovery vessel and project/oversize cargo carrier
  - Vessel length comparable to modern Baltic icebreakers
- Icebreaking capability previously verified in model tests
  - Low icebreaking resistance in level ice
  - Excellent maneuverability and ability to break out from channels
  - Continuous ridge penetration in astern direction
- Seakeeping tests were also carried out
  - To determine the behavior and of the novel hull form in heavy seas
  - To determine forces in Crossdeck in waves
Trimaran icebreaker

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Length over all</td>
<td>100.0 m</td>
</tr>
<tr>
<td>Length, dwl</td>
<td>92.2 m</td>
</tr>
<tr>
<td>Breadth, dwl</td>
<td>38.6 m</td>
</tr>
<tr>
<td>Draft, dwl/max</td>
<td>8.0 m/8.5 m</td>
</tr>
<tr>
<td>Power plant</td>
<td>Combined diesel-electric/mechanical:</td>
</tr>
<tr>
<td></td>
<td>- one main engine mechanically coupled to CPP</td>
</tr>
<tr>
<td></td>
<td>- two main generating sets</td>
</tr>
<tr>
<td></td>
<td>- one harbour generator</td>
</tr>
<tr>
<td>Propulsion power</td>
<td>6,500 kW (mechanical CPP)</td>
</tr>
<tr>
<td></td>
<td>2 x 3,500 kW (diesel-electric azimuth thrusters)</td>
</tr>
<tr>
<td>Bollard pull</td>
<td>150 tonnes</td>
</tr>
<tr>
<td>Icebreaking capability</td>
<td>abt. 6 kn @ 0.8 m</td>
</tr>
<tr>
<td></td>
<td>abt. 2 kn @ 1.5 m</td>
</tr>
</tbody>
</table>

Co-financed by the European Union
Trans-European Transport Network (TEN-T)
Oblique icebreaker

- Aker Arctic developed the oblique icebreaker concept in the 1990s as Aker ARC 100
- First vessel delivered and in service
  - NB508 Baltika, built by Arctech Helsinki Shipyards in 2014
  - Performance verified with full scale tests in the Russian Arctic; design icebreaking capability exceeded in ahead, astern and oblique icebreaking
  - Excellent overall operational capability in ice
- As part of the WINMOS project, the oblique icebreaker concept was further developed:
  - Higher ice class, increased icebreaking and general operational capability
  - Includes "lessons learned" from NB508 Baltika
  - Oil recovery capability retained from original concept
  - Escort capability (towing notch) added
  - Vessel size and propulsion power comparable to IB Voima
Oblique icebreaker

Length over all 87.5 m
Length, dwl 78.5 m
Breadth, dwl 20.0 m
Draft, dwl/max 7.0 m/7.5 m
Power plant Diesel-electric:
   - three main generating sets
   - one harbour generator
Propulsion 3 x 3,500 kW (azimuth thrusters)
Icebreaking capability abt. 5 kn @ 1.0 m
                        abt. 2 kn @ 1.5 m
                        abt. 4 kn @ 0.6 m (50 m wide channel)
Winternavigation system change factors

- **Traffic flows**
  - Changes in transport volumes
  - New ship sizes

- **Merchant vessels independent ice going capabilities**
  - SOX > Fuel prize > no incentive to use extra power
  - EEDI > focus on open water performance

- **Operator competence**
  - Modern manning practices reduce possibilities to assure long term experience base onboard

- **Climate change**
  - Time span, variation between winters

- **Renewal of icebreaker capacity**
  - Scale of investment
  - Availability from possible commercial sector of icebreaking
EEDI and SOX will increase need of assistance due to weaker merchant vessels of the future

Assisted vessels, development trends
**EXAMPLE of basic icebreaker, StBy/Ops 210/180 d/y, rate 3%**

**Investment and operations, no fuel 286,5M€/50y**

<table>
<thead>
<tr>
<th>Vessel name</th>
<th>Perusmurtaja 1</th>
</tr>
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<tbody>
<tr>
<td>Vessel type (1= basic icebreaker, 2 = multi-use icebreaker)</td>
<td>1</td>
</tr>
<tr>
<td>Fuel type (1=diesel, 2= LNG)</td>
<td>1</td>
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<tr>
<td>Start of use, dd.mm.yyyy</td>
<td>1.7.2016</td>
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<tr>
<td>No. of years in use after start of use</td>
<td>50</td>
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<tr>
<td>Capital cost (return requirement), % p.a.</td>
<td>3.00%</td>
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<tr>
<td>Investment cost (remaining unamortized investment cost if existing vessel), €</td>
<td>95 000 000</td>
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<tr>
<td>Renovation 1 (used to calculate annual capital cost), €</td>
<td>8 000 000</td>
</tr>
<tr>
<td>Renovation 2 (used to calculate annual capital cost), €</td>
<td>5 000 000</td>
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<tr>
<td>Capital amortization period, years</td>
<td>20</td>
</tr>
<tr>
<td>Renovation 1 amortization period, years</td>
<td>15</td>
</tr>
<tr>
<td>Renovation 2 amortization period, years</td>
<td>15</td>
</tr>
<tr>
<td>Yearly personnel cost (multi-purpose icebreakers), €/year</td>
<td>0</td>
</tr>
<tr>
<td>Yearly personnel cost (basic icebreaker), €/year</td>
<td>1 200 000</td>
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<tr>
<td>Variable personnel cost (basic icebreaker), €/operation day</td>
<td>5 000</td>
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<tr>
<td>Yearly maintenance and management cost, €/year</td>
<td>700 000</td>
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<td>Level of use 1, %</td>
<td>0%</td>
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<tr>
<td>Additional income 1, €/day (for days in a year excluding stand-by days)</td>
<td>0</td>
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<tr>
<td>Life cycle 1 period, years</td>
<td>0</td>
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<tr>
<td>Level of use 2, %</td>
<td>0%</td>
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<tr>
<td>Additional income 2, €/day (for days in a year excluding stand-by days)</td>
<td>0</td>
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<td>Life cycle 2 period, years</td>
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<tr>
<td>Level of use 3, %</td>
<td>0%</td>
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<tr>
<td>Additional income 3, €/day (for days in a year excluding stand-by days)</td>
<td>0</td>
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<tr>
<td>Life cycle 3 period, years</td>
<td>0</td>
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<tr>
<td>Stand-by fee, €/stand-by day</td>
<td>23 000</td>
</tr>
<tr>
<td>Operation fee, €/operation day</td>
<td>5 000</td>
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